

# MULTIPLE CHANNEL RECORDING OF THE ARTICULAR CRACK ASSOCIATED WITH MANIPULATION OF THE METACARPOPHALANGEAL JOINT

## An Observational Study

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### **Abstract:**

*Background:* The audible release or cracking sound associated with spinal manipulation is familiar to practitioners of spinal manipulative therapy. Furthermore, some authors believe the articular crack to be at least in part responsible for the therapeutic benefits derived from spinal manipulative therapy. Although some research has been directed towards the investigation of some aspects of this phenomenon, little research has been conducted in order to establish from which side and vertebral level the audible release occurs during the manipulative process.

*Objective:* To assess the reliability and accuracy of multiple surface mounted microphones to detect the audible release of the target joint during manipulation of the third metacarpophalangeal joint.

*Design:* Observational study.

*Setting:* Private practice of chiropractic, Ringwood, Victoria, Australia.

*Participants:* Twenty volunteers recruited from staff and patients of the private practice of chiropractic.

*Method:* Eight omnidirectional microphones were affixed to the palmar surface of the hand. Microphone No.1 was positioned directly over the third metacarpophalangeal joint while the remaining microphones were arranged in a uniform pattern over the palmar surface of the hand. Manipulation in the form of long axis traction was then applied to the third metacarpophalangeal joint. Where an audible release was associated with the manipulation the resultant signals were captured via computer and stored for later analysis.

*Main Outcome Measure:* A difference of greater than one volt in peak amplitude between the microphone positioned over the target joint and the other microphones. The student's t-test was then applied to the data in order to determine if the mean output of the target joint microphone was statistically different to the mean output of the other microphones.

*Results:* A total of eighteen manipulations resulted in nineteen audible release signals. The mean voltage of channel 1 was consistently greater than all the other channels in this group of subjects. This difference was statistically significant for all the channels.

*Conclusion:* This research suggests that multiple surface mounted microphones are capable of consistently detecting the audible release from the target joint, with manipulation directed to the third MCP joint. It is hoped that this method will be able to be applied to the audible release associated with spinal manipulative therapy and a better understanding of the manipulative process will ensue.

**Key Indexing Terms:** Joint crack, cavitation, noise, sound, audible release, vibration, recording, manipulation, metacarpophalangeal joint, spine.

### **INTRODUCTION**

The articular crack associated with spinal manipulative therapy (SMT) is familiar to most practitioners of that discipline and is regarded by some to be a sign of a successful manipulation and the difference between manipulation and mobilisation <sup>(1)</sup>. Others place little significance on the joint crack, however most agree that if nothing else it suggests that the joint surfaces have indeed been separated <sup>(2-4)</sup>. Based on earlier research on manipulation of the metacarpophalangeal (MCP) joint <sup>(5-7)</sup>, it appears that the audible release is associated with a rapid separation of the joint surfaces and cavitation within the intra-articular fluid. Furthermore, it has been hypothesised that the audible release or sudden joint separation may be the mechanism responsible for initiating certain reflex responses associated with SMT <sup>(8)</sup>. Regardless of any therapeutic benefit, from clinical experience, many patients and practitioners alike feel less than satisfied if a manipulative procedure fails to elicit an audible release <sup>(5)</sup>.

The interpretation of joint sounds for diagnostic purposes probably dates back to prior 1848 and is mentioned in Laennec's treatise on mediate auscultation <sup>(9)</sup>. With the development of the stethoscope these sounds could be amplified to an audible level, but it was not until the age of the personal computer and modern advancements in the field of electronics that any worthwhile research could be undertaken. Basically, two different techniques have been employed to capture the joint crack signal, microphones and piezoelectric accelerometers. However, with respect to the recording of the audible release associated with SMT, the majority of earlier research has

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concentrated either on sound spectrum analysis or on force/time relationships to the cavitation process<sup>(10-14)</sup>. If the audible release is an important part of the therapeutic effect derived from SMT there are some obvious benefits in determining from which side and vertebral level the sound emanates from during the manipulative process.

Earlier research to determine the origin of the joint crack sound has focused on the MCP joint, as this joint is easily manipulated, and is able to be imaged through the joint plane during the manipulative procedure. The purpose of this study is to determine the consistency of multiple surface mounted microphones to detect the audible release of the target joint during manipulation of the third MCP joint.

The aim of this project was to demonstrate that multiple surface mounted microphones are capable of consistently identifying the target joint with respect to manipulation of the third MCP joint.

## MATERIALS AND METHODS

Twenty subjects were recruited from the staff and patients of a private chiropractic practice to undergo manual manipulation of the MCP joints of both hands. The manipulative technique was in the form of long axial traction to the third MCP joint. The operator's left hand grasped the subject's distal forearm, to stabilise the hand, while the proximal third phalanx was gasped between the first and second fingers of the operator's right hand. A gradual traction force was then applied with the operator's right hand to the target joint until an audible cracking sound was produced. This technique is similar to that employed in some previous studies on manipulation of these joints<sup>(1,5-7)</sup>. Prior to the procedure, informed consent to participate in this study was obtained from each subject.

Prior to the manipulation, each subject had affixed to the palmar surface of the hand eight Realistic Electrec Condenser omnidirectional microphones, with a frequency response of 50-15000 Hz and sensitivity of  $-72\text{dB} \pm 4\text{dB}$ , (Tandy Electronics, Chadstone, Victoria). Each microphone was colour coded and numbered from 1-8 to correspond with each recording channel. Microphone 1 was placed over the third MCP joint while the remaining seven microphones were arranged on either side of microphone 1, distally to proximally, with microphone 8 being affixed over the carpal joints (Fig. 1, 2 & 3).

The microphones were calibrated using a Type 1562-A sound level calibrator, (General Radio, Concord, Massachusetts, USA), and later adjusted, via computer software, to a differential of 11/100ths of a volt. In order to minimise skin friction noise and other artefacts the microphones were mounted in a modified plastic suction cup (Romak Hardware Distributors (Aust) Pty. Ltd., Bayswater, Victoria, Australia) and attached to the skin via double sided adhesive discs (3M Australia Pty. Ltd.,

Figure 1. Microphone placement on left hand.

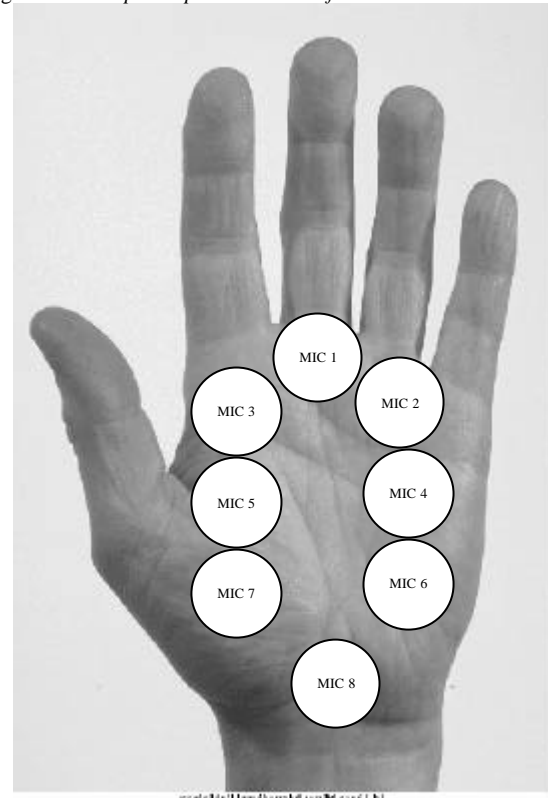


Figure 2. Microphone placement and pre-amplifier.

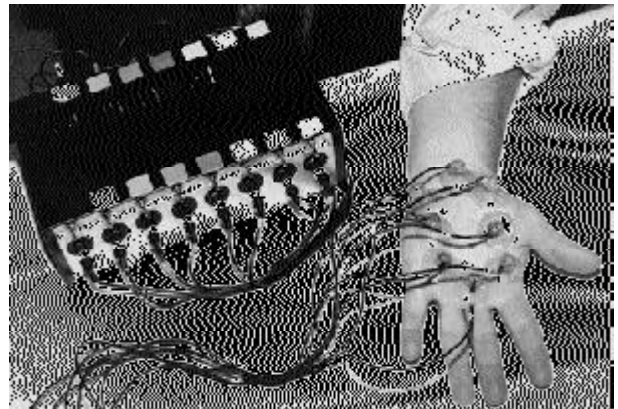


Figure 3. Manipulation set-up.



# RECORDING OF THE ARTICULAR CRACK REGGARS

Glen Waverley, Victoria, Australia). To avoid direct skin contact, the microphones were positioned inside the cups approximately 2 millimetres from the contact surface. Each mounting cup was vented via two 2 millimetre holes drilled into either side of the cup, between the contact surface and the microphone. The microphones in turn were connected to eight shielded, stereo pre-amplifiers, Cat/No 576237, (Videotronics Pty. Ltd., Box Hill, Victoria, Australia) which were connected to a DT34-EZ, 12-bit 250kHz, eight channel data acquisition board (Total Turnkey Solutions Pty. Ltd., Coburg, Victoria, Australia). Captured signals were then processed on an IBM compatible personal computer at 25,000 samples per second, per channel, and stored and displayed via a customised software program HP Vee5 (Hewlett Packard, Victoria, Australia).

The computer hardware and software equipment enabled each joint crack to be simultaneously recorded for each channel. Each joint crack sound wave form was then analysed via the computer software in the time and amplitude domains to determine and compare the greatest amplitude of all eight recorded channels.

In this study channel 1, over the target MCP joint, acted as the treatment group and all the other channels acted as the controls. The statistical analysis employed the student's t-test to determine if the mean output at the target joint microphone was statistically different to the mean output of the other microphones. With 15 subjects, the study has approximately 95% power to detect a significant student's t-statistic at the 5% significance level.

## RESULTS

Twenty individuals were recruited for the study and subjected to the manipulative and recording protocol on either hand. Of these twenty subjects, only nine produced an audible cracking sound when manipulated and three of these subjects were re-manipulated, with a minimum of three days between manipulations. Audible cracking sounds were recorded in both hands with six subjects, while manipulation of the remaining six subjects only resulted in a cracking sound being produced from one hand. A typical eight channel wave form of the recorded joint crack is displayed in Figure 4. Further, a single manipulation of one subject resulted in two distinct cracking sounds from the same joint. In total nineteen individual cracking sounds were produced and recorded for later analysis, the raw data of which is presented in Table 1.

The results of the statistical analysis are presented in Table 2. The mean voltage of channel 1 was consistently greater than all the other channels in this group of subjects. This difference was statistically significant for all the channels. The mean difference of all the channels compared to channel 1 was 3.45 volts. However, the peak amplitude of thirteen joint crack recordings were "clipped" indicating

Figure 4.

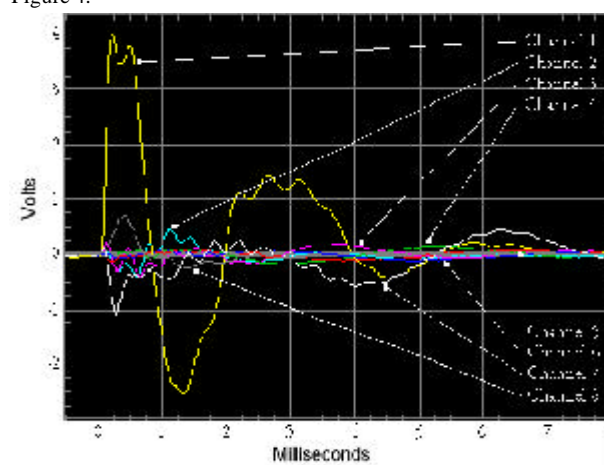


Table 1.

Subject	Channel/Peak Amplitude/Volts							
	1	2	3	4	5	6	7	8
1	4.08	0.45	0.4	0.18	0.14	0.12	1.12	0.71
2	1.29	0.25	0.25	0.1	0.2	0.16	0.02	0.02
3	4.21	0.61	0.55	0.04	0.37	0.42	0.13	0.07
4	4.21	0.48	0.55	0.05	0.07	0.05	0.05	0.04
5	3.47	0.48	0.5	0.05	0.05	0.3	0.15	0.25
6	4.24	0.66	0.32	0.05	0.08	0.05	0.1	0.26
7	3.66	0.28	1.09	0.04	0.14	0.08	0.07	0.15
8	3.99	0.32	0.33	0.04	0.05	0.09	0.16	1.93
9	4.24	0.41	1.26	0.04	0.04	0.16	0.35	0.79
10	4.28	0.52	1.64	0.05	0.05	0.13	0.31	0.9
11	4.3	0.54	0.31	0.04	0.05	0.09	0.3	0.09
12	4.15	0.34	0.62	0.04	0.04	0.22	0.93	0.35
13	4.3	0.38	1.41	0.32	0.31	0.25	0.42	0.47
14	4.3	1.17	0.82	0.49	0.2	0.4	0.25	0.23
15	1.96	0.14	0.17	0.12	0.06	0.11	0.07	0.32
16*	4.24	0.51	1.36	0.43	0.36	0.43	0.43	3.51
17	4.3	0.48	1.42	0.71	0.2	0.14	0.15	0.51
18	3.02	0.29	0.25	0.1	0.07	0.07	0.09	0.17
19	4.29	0.51	0.92	0.42	0.26	0.14	0.15	0.38
Mean	3.82	0.46	0.75	0.17	0.14	0.18	0.28	0.59

\* Secondary crack from single manipulation

Table 2.

Channels	Mean difference	95% CI	Std Error	t Statistic *
1 & 2	3.35	2.99 – 3.72	0.17	19.29
1 & 3	3.07	2.71 – 3.43	0.17	18.09
1 & 4	3.64	3.24 – 4.04	0.19	19.19
1 & 5	3.67	3.26 – 4.08	0.19	18.99
1 & 6	3.64	3.23 – 4.04	0.19	18.93
1 & 7	3.54	3.15 – 3.93	0.18	19.26
1 & 8	3.23	2.73 – 3.73	0.24	13.46
Mean	3.45			

\* All t Statistics p<0.0001

that they had exceeded the maximum potential amplitude of the recording hardware.

## DISCUSSION

The cracking sound associated with joint manipulation has for many years been of interest to many researchers, including some with no interest in manual therapy. Based on an original investigation of this phenomenon by Roston and Haines<sup>(15)</sup>, Unsworth et al<sup>(6)</sup> using human subjects and a model constructed to simulate the MCP joint, applied

axial traction to the joints and models to produce the familiar cracking sound. These researchers observed a radiological area of high density within the joint space in only those joints, which when tractioned, produced an audible cracking sound. They hypothesised that the cracking sound was due to cavitation within the intra-articular fluid. As the traction force increased across the joint, the joint volume increased and the joint fluid partial pressure decreased, causing the intra-articular gases to be drawn out of solution, creating the gas bubble and which represented the area of high density on the radiograph. A subsequent net flow of fluid into this low pressure region collapsed the gas bubble, producing the audible cracking sound. Watson et al<sup>(16)</sup>, using high speed cineradiography to investigate the cracking sound, demonstrated the formation of a gas bubble in less than 8.3ms, when a traction force was applied to the joint and that after the crack there was a significant increase in the joint space. More recently Mierau et al<sup>(1)</sup> using a series of radiographs taken prior to and post manipulation of the third MCP joint demonstrated that a radiographically visible gas arthrogram was present after the joint was manipulated in 39 of the 42 joints that produced an audible crack.

The audible release or joint crack is thought by many authors to be responsible for at least part of the therapeutic benefit derived from SMT procedures<sup>(17-19)</sup>. The majority of the empirical evidence relating to the therapeutic effects of the audible release associated with SMT, has in the main been founded on earlier research relating to joint cracking from manipulation of the MCP joints<sup>(1, 5, 20)</sup>. Sandoz<sup>(18)</sup> states that after the joint crack there is a gain in the range of movement, which is not limited to the direction of manipulation. Mierau et al<sup>(1)</sup> compared manipulation with mobilisation of the MCP joints and found that manipulation, accompanied by a cracking sound, resulted in a significant increase in passive joint flexion.

Although the exact mechanism responsible for the cracking sound has not yet been established<sup>(21)</sup>, it is generally accepted, with respect to manipulation of the MCP joint, that whatever the cause, the sound is generated from within the manipulated joint. Unfortunately there has been very little research with respect to, how and from where the cracking sound associated with SMT is generated. Herzog et al<sup>(22)</sup> using accelerometers and high speed cinematography, to measure relative bone movements during SMT, to the T12 vertebrae of a post-rigor mortis cadaver, detected a cavitation sound from one of the manipulative thrusts applied to T12. As the accelerometer was affixed to the spinous process of the T12 vertebrae the authors suggested that it most probably emanated from either the facet joints at the T11/T12 or T12/L1 vertebral level. Reggars and Pollard<sup>(23)</sup> conducted an observational study, using surface mounted microphones, to determine the side of the joint crack in response to side specific diversified rotary manipulation of the cervical spine. Their research suggested that that

side of the audible release occurred on the side to which the neck was rotated and not on the side to which the manipulative thrust was applied.

Cassidy et al<sup>(24)</sup> criticise any technique that employs a "shotgun approach". In reviewing previous studies of spinal manipulation they are critical of the criteria used to select the level and direction of the manipulative treatments. They state that in some studies the manoeuvres are applied non-specifically and that in such cases it is possible that the direction and level of the manipulation is wrong. Furthermore, Haldeman<sup>(25)</sup> has stated that "The large variety of techniques within the field of spinal manipulation have different therapeutic goals and are administered according to different biomechanical or physiologic principles". Therefore, in order to better understand the manipulative process further research should be undertaken and directed toward determining from what side and vertebral level the audible release will occur during any given SMT technique. Such understanding may lead to SMT being more specific and in turn may result in better health outcomes from improved technique modification.

The current study suggests that during manipulation of the third MCP joint a skin surface mounted microphone positioned over the target joint is capable of consistently identifying the audible release of that joint. Furthermore, it appears that the sensitivity of these microphones is such that they are capable of consistently identifying the audible release of the manipulated joint at relatively small distances from each other, given that at least two of the other microphones were positioned approximately 3cm on either side of the target joint microphone. The sensitivity of these microphones may in fact be greater than this research suggests as thirteen of the recorded signals from the target joint microphone were "clipped". Therefore, it is not unreasonable to assume, that for these recordings, the peak amplitude difference between channel 1 and the other channels was indeed greater than what was recorded.

It is also worthy to note that for the one manipulation which produced two distinct cracking sounds, both the target joint microphone signals were significantly higher in amplitude than those recorded from the remaining microphones. This would indicate that one joint has the potential for multiple joint cracks and may possibly explain the multiple joint cracks detected in the study by Reggars and Pollard<sup>(23)</sup>.

Of further interest is that in three of the manipulations, the microphone recorded signal with the second highest amplitude emanated from the microphone most distant to that of the target joint, and positioned over the carpal bones of the wrist. This anomaly may be due to the fact that the soft tissues have a significant dampening effect on low frequency vibrations. It is postulated that the bone vibration associated with the cracking sound was

# RECORDING OF THE ARTICULAR CRACK REGGARS

transmitted directly along the third metacarpal bone to the carpal bones, thus to some degree avoiding some of this dampening effect.

Whether this protocol is applicable to and capable of identifying the exact location of the audible release associated with SMT remains to be seen but it should form the foundation for further research in this area.

## CONCLUSION

This research suggests that multiple surface mounted microphones are capable of consistently detecting the audible release of the target joint with respect to manipulation of the third MCP joint. It is hoped that this method will be able to be applied to the audible release associated with SMT and a better understanding of the manipulative process will ensue.

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